Attorney Docket No.: 8021-223 (SS-19132-US)

REMOTE PLASMA ENHANCED CLEANING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to Korean Patent Application No. 2003-21923, filed on April 8, 2003, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD OF THE INVENTION

The present invention relates, generally, to a cleaning apparatus used in a process of manufacturing a semiconductor device, and more particularly, to a remote plasma enhanced cleaning apparatus.

BACKGROUND

Generally, during a process of manufacturing a semiconductor device, a native oxide film is formed on a silicon wafer. The native oxide film can be removed by employing a wet cleaning method using a chemical solution, for example, a diluted HF solution. However, as semiconductor devices have become more highly integrated, wet cleaning methods have certain limitations. As a result, dry cleaning methods have replaced wet cleaning methods. Also, a

remote plasma enhanced cleaning apparatus has been developed for employing a dry cleaning method.

FIG. 1 is a schematic view of a conventional remote plasma enhanced cleaning apparatus. Referring to FIG. 1, a main body 10 of the conventional remote plasma enhanced cleaning apparatus includes a buffer chamber 12 and a loadlock chamber 14. The buffer chamber 12 includes a carrier robot (not shown) to carry a silicon wafer loaded into the loadlock chamber 14 to the buffer chamber 12. Cassette parts 16 on which the silicon wafer is loaded are connected to a side of the main body 10 adjacent to the loadlock chamber 14. The silicon wafer is loaded into the loadlock chamber 14 via the cassette parts 16.

Adsorption chambers 18 are connected to a side of the main body 10 adjacent to the buffer chamber 12. The adsorption chambers 18 are used to react a native oxide film on the silicon wafer, which has been carried from the buffer chamber 12, with active gas species to form a reaction film including a mixture of Si, N, H, and F. To be more specific, in the adsorption chambers 18, a mixture of a nitrogen gas and a hydrogen gas is activated using remote plasma to produce the active gas species, and a nitrogen trifluoride (NF_3) gas is then added to the active gas species during the downward flow of the active gas species in the adsorption chambers 18 to activate the NF_3 gas. Thereafter, the

active gas species react with the native oxide film on the silicon wafer to form the reaction film.

An anneal chamber 20 is connected to a side of the main body 10 adjacent to the buffer chamber 12. The anneal chamber 20 is used to anneal the silicon wafer having the reaction film formed thereon, which has been carried from the adsorption chambers 18 via the buffer chamber 12. The annealing results in sublimating and removing of the reaction film on the silicon wafer.

A cooling chamber 22 is connected to a side of the main body 10 adjacent to the loadlock chamber 14. The cooling chamber 22 is used to cool the silicon wafer, which has been carried from the anneal chamber 20 via the buffer chamber 12.

However, in the conventional remote plasma enhanced cleaning apparatus, the buffer chamber 12, the adsorption chambers 18, the anneal chamber 20, and the cooling chamber 22 are of a single type. In other words, only one silicon wafer may be processed in the buffer chamber 12, the adsorption chambers 18, the anneal chamber 20, and the cooling chamber 22 using the conventional remote plasma enhanced cleaning apparatus. Thus, since the conventional remote plasma enhanced cleaning apparatus provides a very low throughput, it is not suitable for mass-producing semiconductor devices.

In a case where the buffer chamber 12, the adsorption chambers 18, the anneal chamber 20, and the cooling chamber 22 of the conventional remote

plasma enhanced cleaning apparatus is of a batch type to improve the throughput, the silicon wafer may not be uniformly cleaned, i.e., adsorbed, annealed, and cooled. As a result, a process of cleaning the silicon wafer may be unsatisfactory. Also, since the diameter of the silicon wafer may increase to 300mm, it is difficult to support the silicon wafer in the buffer chamber 12, the adsorption chambers 18, the anneal chamber 20, and the cooling chamber 22 using the conventional remote plasma enhanced cleaning apparatus.

Therefore, a need exists for a remote plasma enhanced cleaning apparatus that is capable of uniformly cleaning a silicon wafer while increasing throughput.

SUMMARY OF THE INVENTION

Exemplary embodiments of the invention generally include a remote plasma enhanced cleaning apparatus capable of improving the uniformity of a cleaning process and increasing throughput.

According to an exemplary embodiment of the present invention, a remote plasma enhanced cleaning apparatus comprises a main process chamber, and a loadlock chamber connected to the main process chamber. The main process chamber comprises a staging device adjacent to the loadlock chamber for loading silicon wafers from the loadlock chamber into the main process chamber and for unloading the silicon wafers from the main process chamber into the

loadlock chamber, a carrier robot disposed in a center portion of the main process chamber, wherein the carrier robot rotates and moves around the center of the main process chamber and transfers the silicon wafers to an adsorption assembly, an anneal assembly, and a cooling assembly which are disposed in the main process chamber around the carrier robot.

According to another exemplary embodiment, the adsorption assembly may comprise two adsorption stages for holding the silicon wafers during an adsorption process.

According to another exemplary embodiment, the adsorption assembly comprises an adsorption chamber comprising adsorption stages for holding the silicon wafers, and a remote plasma generator which is disposed above the adsorption chamber to transforms a N_2 gas, a H_2 gas, and a NF_3 gas into plasma to form active gas species.

The anneal assembly may comprise two anneal stages for holding the silicon wafers during an annealing process. The anneal assembly may comprise an anneal chamber comprising anneal stages for holding the silicon wafers, and heating means for heating the silicon wafers on the anneal stages.

The cooling assembly may comprise two cooling stages for holding the silicon wafers during a cooling process. The cooling assembly may comprise a cooling chamber including cooling stages for holding the silicon wafers, and cooling means for cooling the silicon wafers on the cooling stages.

According to another exemplary embodiment, a remote plasma enhanced cleaning apparatus comprises a main process chamber, a loadlock chamber connected to the main process chamber. The main process chamber comprises a staging device adjacent to the main process chamber for loading silicon wafers from the loadlock chamber into the main process chamber and for unloading the silicon wafers from the main process chamber into the loadlock chamber, a carrier robot disposed in a center of the main process chamber, wherein the carrier robot rotates and moves around the center of the main process chamber, an adsorption assembly disposed adjacent to the carrier robot in the main process chamber, wherein the adsorption assembly allows native oxide films on the silicon wafers to react with active gas species to form reaction films including a mixture of Si, N, H, and F, and wherein the active gas species are formed by transforming a N_2 gas, a H_2 gas, and a NF_3 gas into plasma, an anneal assembly disposed adjacent to the adsorption chamber and the carrier robot in the main process chamber, wherein the anneal assembly heats and sublimates the reaction films on the silicon wafers, and a cooling assembly disposed adjacent to the anneal assembly and the carrier robot in the main process chamber, wherein the cooling assembly cools the heated silicon wafers.

According to another exemplary embodiment, the adsorption assembly may comprise two adsorption stages for holding the silicon wafers during an adsorption process. The adsorption assembly may comprise an adsorption

chamber comprising adsorption stages for holding the silicon wafers, a first gas injection pipe connected to a gas distributor located at an upper portion of the adsorption chamber, wherein a mixture of a N_2 gas and a H_2 gas is injected into the adsorption chamber via the first gas injection pipe connected to the gas distributor, a remote plasma generator to transform the mixture of N2 and H2 gases into plasma using remote plasma to form the active gas species, and a second gas injection pipe disposed at a side of the adsorption chamber to inject a NF_3 gas into the adsorption chamber.

The anneal assembly may comprise two anneal stages for holding the silicon wafers during an annealing process. The anneal assembly may comprise an anneal chamber comprising anneal stages for holding the silicon wafers, and heating means for heating the silicon wafers on the anneal stages to sublimate the reaction films on the silicon wafers.

The cooling assembly may comprise two cooling stages for holding the silicon wafers during a cooling process. The cooling assembly may comprise a cooling chamber including cooling stages for holding the silicon wafers, and cooling means for cooling the silicon wafers on the cooling stages.

These and other exemplary embodiments, features, aspects and advantages of the present invention will become more apparent by the following detail description exemplary embodiments when read in conjunction with the accompany drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a conventional remote plasma enhanced cleaning apparatus.

FIG. 2 is a schematic view of a remote plasma enhanced cleaning apparatus, according to an exemplary embodiment of the present invention.

FIG. 3 is a schematic cross-sectional view of an adsorption assembly in the remote plasma enhanced cleaning apparatus of FIG. 2.

FIG. 4 is a schematic cross-sectional view of an anneal assembly in the remote plasma enhanced cleaning apparatus of FIG. 2.

FIG. 5 is a schematic cross-sectional view of a cooling assembly in the remote plasma enhanced cleaning apparatus of FIG. 2.

FIGS. 6 and 7 are schematic views illustrating the operation of the remote plasma enhanced cleaning apparatus of FIG. 2, according to exemplary embodiments of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Reference will now be made in detail to exemplary embodiments of the present invention as illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout.

FIG. 2 is a schematic view of a remote plasma enhanced cleaning apparatus, according to an exemplary embodiment of the present invention.

Referring to FIG. 2, the remote plasma enhanced cleaning apparatus includes a main process chamber 100 and a loadlock chamber 300 connected to the main process chamber 100. A carrier robot 150 is installed at the center of the main process chamber 100 to rotate and carry a silicon wafer around the center of the main process chamber 100. Preferably, the carrier robot 150 includes six arms. A load and/or unload stage 400, or a staging device, is installed in the main process chamber 100 adjacent to the loadlock chamber 300 to load the silicon wafer from the loadlock chamber 300 into the main process chamber 100 and unload the silicon wafer from the main process chamber 100 into the loadlock chamber 300.

An adsorption assembly 500 is installed adjacent to the carrier robot 150 in the main process chamber 100. The adsorption assembly 500 includes two adsorption stages. As will be described later, the adsorption assembly 500 is used to react native oxide films on silicon wafers, which have been carried from the load and/unload stage 400, with active gas species to form reaction films including a mixture of Si, N, H, and F on the silicon wafers. To be more specific, in the adsorption assembly 500, a mixture of a nitrogen gas and a hydrogen gas is activated using remote plasma to produce the active gas species, and a NF_3 gas is added to the active gas species during the downward flow of the active gas species in the adsorption chamber 501 to activate the NF_3 gas. As a result,

the active gas species react with the native oxide films on the silicon wafers to form the reaction films.

An anneal assembly 700 is installed adjacent to the adsorption assembly 500 and the carrier robot 150 in the main process chamber 100. The anneal assembly 700 includes two anneal stages. The anneal assembly 700 is used to anneal the silicon wafers having the reaction films, which have been carried from the adsorption assembly 500. The annealing of the silicon wafers sublimates and removes the reaction films on the silicon wafers.

A cooling assembly 900 is installed adjacent to the anneal assembly 700 and the carrier robot 150 in the main process chamber 100. The cooling assembly 900 includes two cooling stages. The cooling assembly 900 is used to cool the silicon wafers that have been carried from the anneal assembly 700.

As described above, the remote plasma enhanced cleaning apparatus of the present invention can include an adsorption assembly, annealing assembly and cooling assembly, wherein each of the assemblies have two stages, and a rotary carrier robot having six arms to sequentially supply silicon wafers to the assemblies.

To be more specific, the remote plasma enhanced cleaning apparatus of the present invention comprises an adsorption assembly, an anneal assembly, and a cooling assembly, wherein each of the assemblies includes two stages. Thus, each of the assemblies allows the loading and processing of at least two

silicon wafers. In other words, after processing is completed within each of the assemblies, the silicon wafers are either transferred to another assembly for further processing or delivered to the staging device once the silicon wafers have been cleaned. Accordingly, the remote plasma enhanced cleaning apparatus of the present invention can improve the uniformity of a process for cleaning silicon wafers while substantially increasing throughput.

FIG. 3 is a schematic cross-sectional view of the adsorption assembly 500 in the remote plasma enhanced cleaning apparatus of FIG. 2. Referring to FIG. 3, adsorption chamber 501 of the adsorption assembly 500 includes two adsorption stages 505 which are spaced apart from each other. In addition, the adsorption stages 505 are used to hold silicon wafers during an adsorption process. The adsorption stages 505 are made of electrostatic chucks. Pins 509 are installed on the adsorption stages 505 and move upward and downward via drive mechanisms (not shown) to separate silicon wafers 507 from the adsorption stages 505. When the silicon wafers 507 are separated from the adsorption stages 505, rear surfaces of the silicon wafers 507 can also be cleaned. A gateway 503 is installed adjacent to a side of the adsorption chamber 501. The gateway 503 allows the silicon wafers 507 to be supplied to or removed from the adsorption chamber 501.

A first gas injection pipe 511 is connected to a distributor 517 located at an upper portion of the adsorption chamber 501. A mixture of a N_2 gas and a H_2

gas is injected into the adsorption chamber 501 via the first gas injection pipe 511. A remote plasma generator is installed above the adsorption chamber 501 and includes a microwave generator 513 and a window 515. The widow 515 is connected to the first gas injection pipe 511 and the microwave generator 513. The remote plasma generator transforms the mixture into plasma to form active gas species. In other words, when the mixture of the N_2 gas and the H_2 gas, or gas mixture, passes through the first gas injection pipe 511, the microwave generator 513 transforms the mixture into plasma using a remote plasma method to form the active gas species. To be more specific, the microwave generator 513 generates a microwave, for example, a microwave of 2.45GHz, and transmits the microwave to the gas mixture via the window 515 to transform the gas mixture into plasma, thereby forming the active gas species. In the present embodiment, the adsorption assembly 500 generates plasma using the remote plasma method. However, the adsorption assembly 500 may use an inductively coupled plasma (ICP) method.

Evacuation of the adsorption chamber 501 is performed to allow the active gas species in the first gas injection pipe 511 to flow downward via the distributor 517 to distribute the active gas species throughout the adsorption chamber 501. When the active gas species flow downward in the adsorption chamber 501, a NF_3 gas is injected into the adsorption chamber 501 via a second gas injection pipe 519 located at a side of the adsorption chamber 501 to activate the NF_3 gas.

Thereafter, the active gas species react with the native oxide films on the silicon wafers 507 to form the react films including the mixture of Si, N, H, and F on the silicon wafers 507. A radio frequency (RF) bias may be applied to lower portions of the adsorption stages 505 to accelerate the active gas species and to promote the reaction of the active gas species with the native oxide films. Here, active gas species that have not reacted with the native oxide films are exhausted via exhaust outlets 521 located at a lower portion of the adsorption chamber 501.

FIG. 4 is a schematic cross-sectional view of the anneal assembly 700 in the remote plasma enhanced cleaning apparatus of FIG. 2. Referring to FIG. 4, an anneal chamber 701 of the anneal assembly 700 includes two anneal stages 705 that are spaced apart from each other and are used to hold silicon wafers 707 during an annealing process. The anneal stages 705 are made of electrostatic chucks. Lamps 717 are installed as a heating means to heat the anneal assembly 700. Heating wires 715 are installed in upper portions of the anneal stages 715 to directly heat the anneal stages 705. The anneal assembly 700 anneals the silicon wafers 707 using both the lamps 717 and the heating wires 715. The anneal assembly 700 may also include only one of the lamps 717 and the heating wires 715 to anneal the silicon wafers 707.

Pins 709 are installed on the anneal stages 705 and move upward and downward via drive mechanisms (not shown) to separate the silicon wafers 707

from the anneal stages 705. When the silicon wafers 707 are separated from the anneal stages 705 via the pins 709, native oxide films formed on rear surfaces of the silicon wafers 707 may also be cleaned. A gateway 703 is installed at a side of the anneal chamber 701. The gateway 703 allows the silicon wafers 707 to be supplied to or removed from the anneal chamber 701.

A gas injection pipe 711 is connected to a gas distributor 713 located at an upper portion of the anneal chamber 701. An atmospheric gas, for example, a N_2 gas, is injected into the anneal chamber 701 via the gas injection pipe 711 connected to the gas distributor 713. The atmospheric gas is exhausted via exhaust outlets 719 located at a lower portion of the anneal chamber 701. Arrows of FIG. 4 denote the flow of gas.

FIG. 5 is a schematic cross-sectional view of the cooling assembly 900 of the remote plasma enhanced cleaning apparatus of FIG. 2. Referring to FIG. 5, a cooling chamber 901 of the cooling assembly 900 includes two cooling stages 905 that are spaced apart from each other and are used to hold silicon wafers 907 during a cooling process. The cooling stages 905 are made of electrostatic chucks. Cooling source supply lines 915 are installed in the cooling stages 905, and cooling source supplies 917 are connected to the cooling source supply lines 915. The cooling source supplies 917 supply a cooling source such as helium and the like via the cooling source supply lines 915 in the cooling stages 905 to cool the silicon wafers 907.

Pins 909 are installed on the cooling stages 905 and move upward and downward via drive mechanisms (not shown) to separate the silicon wafers 907 from the cooling stages 905. When the silicon wafers 907 are separated from the cooling stages 905 via the pins 909, the silicon wafers 907 can be effectively cooled. A gateway 903 is installed at a side of the cooling chamber 901. The gateway 903 allows the silicon wafers 907 to be supplied to or removed from the cooling chamber 901.

A gas injection pipe 911 is connected to a gas distributor 913 located at an upper portion of the cooling chamber 901. A cooling gas for directly cooling the silicon wafers 907, for example, a N_2 gas, is injected into the cooling chamber 901 via the gas injection pipe 911 connected to the gas distributor 913. The cooling gas is exhausted via exhaust outlets 919 located at a lower portion of the cooling chamber 901. Arrows of FIG. 5 denote the flow of gas.

The silicon wafers 907 may be cooled by injecting the cooling gas via the cooling source supply lines 915 and the cooling source supplies 917 or by directly injecting the cooling gas into the cooling chamber 901 via the gas injection pipe 911 connected to the gas distributor 913.

FIGS. 6 and 7 are views illustrating various operations of a remote plasma enhanced cleaning apparatus of FIG. 2, according to exemplary embodiments of the present invention. The reference numerals of FIGS. 6 and 7 are referring to like elements as shown FIG. 2.

Referring to FIGS. 6 and 7, the remote plasma enhanced cleaning apparatus includes an adsorption assembly 500, an anneal assembly 700, and a cooling assembly 900, each of which includes two stages, and a carrier robot (150 of FIG. 2) having six concentrically rotating arms. Thus, silicon wafers can be sequentially supplied and cleaned in the remote plasma enhanced cleaning apparatus of the present invention. Here, since the adsorption assembly 500, the anneal assembly 700, and the cooling assembly 900 are enclosed in a main chamber 100, pressures in the adsorption assembly 500, the anneal assembly 700, and the cooling assembly 900 are uniformly maintained when cleaning the silicon wafers.

According to an exemplary embodiment, as shown in FIG. 6, a remote plasma enhanced cleaning apparatus performs a cleaning process by passing a silicon wafer to all stages of the adsorption assembly 500, the anneal assembly 700, and the cooling assembly 900 in a direction indicated by an arrow depicted in FIG. 6. In other words, a silicon wafer is cleaned by passing through stages 1/6 to 6/6. In addition, as a silicon wafer is transferred from one stage to another stage, another silicon wafer can be placed in the vacated stage, thereby simultaneously performing the cleaning process on a plurality of silicon wafers.

According to another exemplary embodiment, as shown in FIG. 7, a remote plasma enhanced cleaning apparatus performs a cleaning process by passing silicon wafers to the adsorption assembly 500, the anneal assembly 700,

and the cooling assembly 900 in a direction indicated by an arrow depicted in FIG. 7. In other words, two silicon wafers are cleaned by passing through assemblies 1/3 to 3/3. In addition, as a pair of silicon wafers is transferred from one assembly to another assembly, another pair of silicon wafers can be placed in the vacated assembly, thereby simultaneously performing the cleaning process on multiple pairs of silicon wafers.

As described above, a remote plasma enhanced cleaning apparatus according to the exemplary embodiments of the present invention can include an adsorption assembly, an anneal assembly, and a cooling assembly, each of which includes two stages, and a carrier robot having six concentrically rotating arms. Thus, the remote plasma enhanced cleaning apparatus can sequentially supply silicon wafers to the various assemblies therein to improve the uniformity of a process for cleaning the silicon wafers and to substantially increase throughput.

In addition, the remote plasma enhanced cleaning apparatus according to the exemplary embodiments of the present invention comprises an adsorption assembly, an anneal assembly, and a cooling assembly that are not of a batch type. As a result, when the diameter of silicon wafers increases to 300mm, the silicon wafers having an increased diameter can be readily cleaned in the adsorption assembly, the anneal assembly, and the cooling assembly of the present invention.

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.